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Monetary Policy Rules and the U.S. Business Cycle: Evidence and Implications

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Monetary Policy Rules and the U.S. Business Cycle: Evidence and Implications

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Abstract

This paper estimates Taylor-type interest rates for the United States allowing for both time and state dependence. It provides evidence that the coefficients of the Taylor rule change significantly over time, and that the behavior of the Federal Reserve over the cycle can be explained using a two-state switching regime model. During expansions, the Federal Reserve follows a rule that can be characterized as inflation targeting with a high degree of interest rate smoothing. During recessions, the Federal Reserve targets output growth and conducts policy in a more active manner. The implications of conducting this type of policy are analyzed in a small scale new Keynesian model.

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I. INTRODUCTION

A. Motivation

Since the beginning of the 21st century, when a new era of "price stability" was reached, several factors have revived interest in monetary policymaking in the United States. The inflation rate kept falling after the 2001 recession, and core CPI inflation reached 1.1 percent by end-2003, causing Federal Reserve officials to show public unease about an unwelcomed risk of deflation. At the same time, concerns about nominal interest rates hitting the zero caused the Fed to use most of its ammunition preemptively and reduce the federal funds rate target sharply to 1 percentage point, the lowest in 40 years, and to keep it at that level for twelve months (between the months of June of 2003 and 2004).

These events have triggered a new debate on how monetary policy should be conducted under extreme but low probability outcomes, from the use of "unconventional" monetary policy tools if the federal funds rate were to hit zero, to the call for a "risk management" approach by Federal Reserve Chairman Alan Greenspan. An important consequence of all these recent developments is that the so-called Taylor rule, that relates the policy instrument of the central bank to a measure of inflation and deviation of real activity from a long-term value, seems to have lost power as an approximation to actual policymaking. More generally, central bankers consistently emphasize that setting monetary policy is a complex process, involving a range of judgmental factors that cannot be condensed into a parametric approach.

This paper provides estimates of Taylor-type monetary policy rules for the United States where asymmetric and nonlinear behavior is allowed, and tries to answer two main questions: first, have coefficients of the Taylor rule changed over time? And second, do the coefficients of the Taylor rule change when economic conditions change? The answer to both questions is yes. The results suggest that, during expansions, the Federal Reserve targets inflation and conducts monetary policy in a highly inertial way, while during recessions, it targets output growth and moves the policy rate more sharply.

The last part of the paper analyzes the consequences of parameter change in a small-scale macroeconomic model. The main result is that output volatility can be further reduced under a state-dependent rule when a cost-push shock hits the economy, but at the cost of higher inflation.

B. How Well Does the Taylor Rule Fit the Data?

The debate on whether central banks should follow a rule rather than discretionary monetary policy has not been settled between academic and policymaking circles. From the academic literature, a tradition of papers starting with Kydland and Prescott (1977) and Barro and Gordon (1983) suggest that a rules-based approach reduces the inflationary bias in monetary policy. More recent research within the class of models that use interest rate rules (i.e., Woodford, 2003 and Clarida, Galí, and Gertler, 1999) suggests that a central bank can manage expectations by committing to a monetary policy rule, thereby facing a more favorable inflation-output stabilization trade off.

In practice, no major central bank wants to tie its hands and commit its future monetary policy actions; discretionary monetary policy is the rule. In recent speeches,[2] Federal Reserve officials have suggested that it would make little sense for any central banker to mechanically follow a simple rule. Such rules might perform fairly well under normal conditions, and can be useful as a benchmark, but they offer no guidance when the economy potentially faces high risks or abnormally large shocks, because of nonlinearities associated with extreme events. Chairman Greenspan is of the view that, given our limited understanding of relevant economic phenomena, a central bank, in conducting monetary policy, should apply judgment and principles of risk management to avoid low-probability extreme events, rather than follow a mechanical rule.

Even when central banks announce that they conduct policy in a discretionary or mostly judgmental way, however, it still might be possible to characterize their average behavior via a relatively simple econometric model. In a highly influential paper, Taylor (1993) showed that during the period from 1987 to 1992, a simple interest rate rule fits the data pretty well for the United States. Taylor suggested the following interest rate rule, relating the federal funds rate, with a measure of a steady state nominal interest rate, consisting of the real interest rate and inflation, and a reaction to deviations from inflation (π_t) and output (y_t) to their long-term (or target) values (π_t^*) and (y_t^*) respectively:

$$i_t = r^* + \pi_t + \gamma_\pi(\pi_t - \pi_t^*) + \gamma_y(y_t - y_t^*)$$

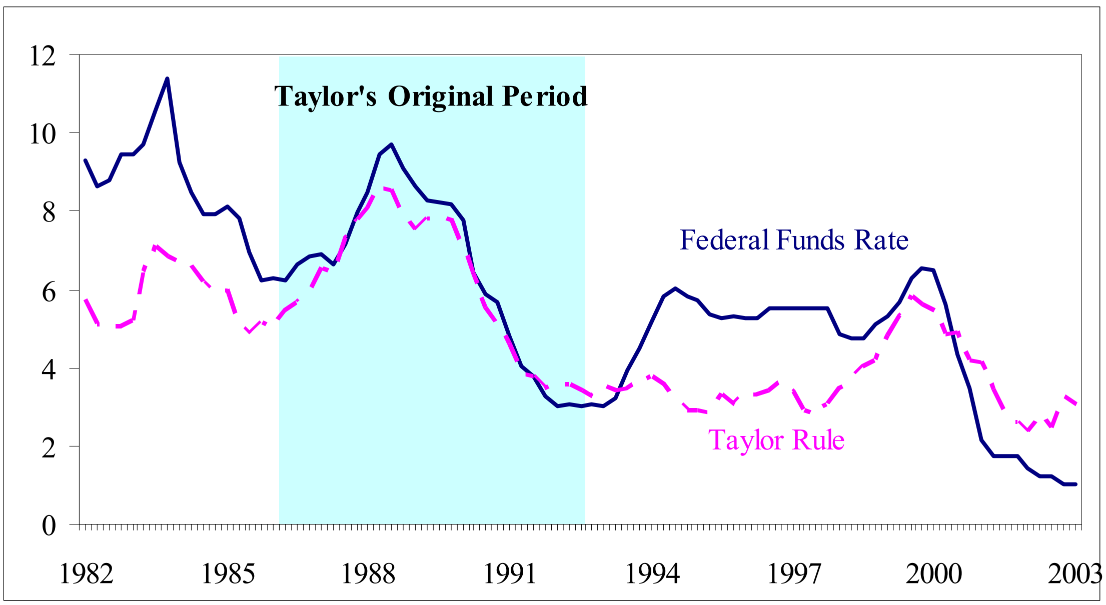
The federal funds rate (i_t) is specified in annualized terms, inflation consists of the last four quarters of the GDP deflator inflation, and the output gap is measured as percent deviations of actual output from long-term (trend) output.[3] In order to keep things as simple as possible, Taylor's paper did not estimate the rule but rather suggested some values for the parameters: the steady state real interest rate r^* was set at 2 percent; the inflation target π_t^*, was also set at 2 percent; implying that the steady state nominal interest rate is 4 percent. The coefficient of the reaction of interest rates to the inflation deviation γ_π, was set at 0.5; and the same value was used for the coefficient of the reaction of the interest rate to the percent deviation of output from its potential value γ_y, 0.5.

[2] See, for instance, Greenspan (2004).

[3] Two main problems arise when using this rule for actual policymaking. First, to obtain the steady state value for the nominal interest rate, estimates of steady-state values for the real interest rate are needed. Taylor assumed a steady-state real interest rate value of 2 percent. The second limitation is that potential output is an unobservable variable. Taylor's guess was a trend growth rate of 2.2 percent between 1984:Q1 and 1992:Q3.

Figure 1 presents the simulation of the Taylor rule using quarterly data between 1982:Q4 and 2003:Q4, using Taylor's parameterization, except for trend growth, which is assumed to be 2.8 percent (the sample mean for the period). The Taylor rule does a good job of explaining the behavior of the Fed between 1987 and 1994, extending by two years Taylor's original study. However, in other periods it does not fit the data so well. For instance, during and after the 2001 recession, the Fed eased monetary policy much faster than what the rule would suggest, and in the past three quarters in particular, the distance exceeds 150 basis points. For the last quarter of 2003, the Taylor rule would suggest a value of 3.1 percent for the federal funds rate, while the actual value is 1 percent. These important deviations have led several analysts as well as Federal Reserve officials to suggest that the Taylor rule might not be a good approximation to actual policymaking after all.

Figure 1. Original Taylor Rule



Sources: Federal Reserve; and Fund staff estimates.

This paper seeks to help reconcile the more nuanced characterization of monetary policy espoused by many policymakers with rules typically estimated in academic analysis. In particular, the paper examines a policy rule whose parameters are not constant, with a focus on whether there is evidence that monetary responses vary systematically over the business cycle. Such behavior would be consistent with the notion that policymakers consider more factors than are captured in a typical monetary response regression,which also captures nonlinearities in the Taylor rule.

The remainder of this paper is organized as follows. Section II estimates a model with time-varying coefficients for the Taylor rule, and we find that the Fed's tolerance to deviations of inflation from its target increases during periods of recession or when other risks come into play. In Section III, we estimate the Taylor rule in a switching regime framework, and we find that the Fed behaves quite differently in booms and recessions. In Section IV, we relate the estimates of the switching regime model to the various chairmen that the Fed has had since 1960. In Section V, we explore the implications of such behavior in a small-scale macro model, and Section VI concludes and provides some directions for future work.

II. Time-Varying Parameters

The empirical literature on monetary policy rules has been typically concerned about structural breaks in the Taylor rule, with an emphasis in the pre- and post-Greenspan years. A typical result, as in Clarida, Galí, and Gertler (2000), is that the policy rule places more weight on inflation stabilization after 1982.[4] However, the results that come from this approach do not allow to discern whether the Fed behaved differently because the preferences of its chairmen were different, or because the economic events or shocks were also different, which required different monetary policy actions, possibly of a nonlinear and asymmetric nature.[5]

Therefore, in this section and the next section of the paper, we examine the following questions:

1. Have the parameters of the Taylor rule changed significantly over time?

2. Does the Fed behave differently when the state of the economy changes?

It might well be that the parameters of the observed rule do not change significantly when averaged overtime, but the Fed uses very different rules in booms and recessions. We study whether the Fed uses one rule in all states of the economy, or it uses various rules depending on its perception of the state of the economy.

In this section, we allow the coefficients of the rule to change not only across sub samples, as is customary in the literature, but at any point in time. We also introduce some modifications to the rule that have been shown to improve its empirical fit. First, we introduce lagged interest rates to capture the tendency of central banks to conduct monetary policy in a "smooth" way. Second, since the output gap can be measured in a variety of ways, we assume that the Federal Reserve targets output growth, which is an observable variable, instead.[6]

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[4] See also Boivin and Giannoni (2003).

[5] For instance, Dolado, María-Dolores, and Naveira (2004) find evidence of nonlinear behavior in the Taylor rule, which they relate to optimal responses to a convex-shaped Phillips curve.

[6] For this specification of the Taylor rule, see Erceg and Levin (2003).

The model to be estimated is as follows:

$$i_t = \rho_t i_{t-1} + (1-\rho_t)(c_t + \gamma_{\pi,t}\pi_t + \gamma_{g,t}\Delta y_t) + \varepsilon_t, \tag{1}$$

where ρ_t is the coefficient measuring interest rate smoothing, Δy_t is output growth, and $\gamma_{\pi,t}$ and $\gamma_{g,t}$ are the time-varying long-run elasticities of the interest rate rule with respect to inflation and output growth. ε_t is a Normally distributed, zero mean *iid* error term.

The time-varying intercept is $c_t^* = r_t^* - (\gamma_{\pi,t} - 1)\pi_t^* - \gamma_{g,t} g_{y,t}^*$. It is not possible to estimate separately the real rate of interest, the inflation target of the central bank, and the target output growth rate ($g_{y,t}^*$) because the Federal Reserve does not announce explicit inflation or output growth targets. Hence, we have to calibrate two of the three parameters to obtain the other. However, the estimates of the constant term do not affect the slope elasticities, as long as the free parameters are not over calibrated.

To conduct the estimation, it is assumed that all the parameters follow a random walk:

$$\begin{aligned}
\rho_t &= \rho_{t-1} + \varepsilon_t^{\rho} \\
c_t &= c_{t-1} + \varepsilon_t^{c} \\
\gamma_{\pi,t} &= \gamma_{\pi,t-1} + \varepsilon_t^{\pi} \\
\gamma_{g,t} &= \gamma_{g,t-1} + \varepsilon_t^{g}.
\end{aligned}$$

Equation (1) and the processes for the parameters can be written in space-state form. In a first step, the parameters of the model (the variances of the five shocks) are estimated via maximum likelihood. Then, the Kalman filter is used to obtain the one-step ahead forecasts and the smoothed series for the coefficients, as in Hamilton (1994).

Figure 2 presents the smoothed series of the parameter estimates, where the shaded areas are the National Bureau of Economic Research (NBER) recession dates.[7] The time-varying model favors a specification where the elasticity of the Taylor rule to the inflation rate and the interest rate smoothing coefficient swing greatly to explain interest rate movements. Except for the Volcker disinflation period, the elasticity of the Taylor rule with respect to inflation decreases during or after the recession (this seems to be particularly the case after the 1990–1991 and the 2001 recessions). During the Volcker disinflation, the coefficient reaches values above 2, and hits a maximum of 2.3 in 1984:Q3. The model also suggests that interest rate smoothing was declining during the 1980s, it became almost zero during the Volcker disinflation, and it increased afterwards, just to decline during the last three years.

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[7] Bayoumi and Sgherri (2004) present similar evidence on time-varying coefficients in the Taylor rule.

Fluctuations in the intercept and the reaction to output growth are less important quantitatively.[8]

It is important to notice that, in addition to NBER recession dates, in periods where the Fed was concerned about other potential high risks in the economy, such as the stock market crash of 1987, the Iraq invasion of Kuwait (fall of 1990), the Russian default (fall of 1998), the September 11, 2001 attacks, and more recently, the risk of deflation, the elasticity of the Fed Funds rate with respect to inflation falls, showing more tolerance with inflation when other risks come to play.

In fact, in the last cyclical episode, the coefficient on inflation declined markedly and became negative after the first quarter of 2001, showing that the Fed was not responding to current inflation, but rather using its ammunition preemptively to avoid, first, the recession and the impact of the terrorist attacks and, second, an unwelcomed fall in the inflation rate. This behavior of the Fed explains why a “traditional” Taylor rule will not fit the data in the most recent period.

Figure 2. Estimates of the Taylor Rule: Time Varying Coefficients, Smoothed Series

Source: Fund staff estimates.

[8] Indeed, the short-term responses $(1-\rho_t)c_t$ and $(1-\rho_t)\gamma_{g,t}$ are constant.

III. A State-Dependent Taylor Rule

The previous section has provided some anecdotal evidence regarding the behavior of the Federal Reserve in periods of recession and in periods where fighting inflation was the most important goal for monetary policy. This section implements a further step in the econometric analysis to discern whether the Federal Reserve behaves consistently its rule whenever economic conditions change. It might well be that according to the views that the Fed has over the economy, it follows different state-contingent rules which, averaged over time, deliver a rule with no changing coefficients, or, on the contrary, with large swings in the coefficients.

Therefore, we estimate a regime switching model for the Taylor rule. The estimation is conducted in two stages. First, we estimate a switching regime model for output growth, as in Hamilton (1994). In a second step, the probabilities obtained using Hamilton's method are used in a weighted least squares regression to obtain the coefficients of the rule in each state. The idea is to capture how policymakers assign probabilities of being in an expansion or a recession, and how they respond to the state of the economy accordingly. The switching regime model is more flexible because it allows to examine what happens when the Fed (or an external observer) believes the economy is in an expansion or recession state with certainty, or when, for instance, it assigns a ¼ probability of being in a recession and a ¾ probability of being in an expansion.[9]

Formally, in the first step, we estimate the following model for output growth[10]:

$$\Delta y_t = c(s_t) + \varepsilon_t$$
$$\text{where } s_t = \{1,2\} \text{ and } \varepsilon_t \sim iidN(0,\sigma^2)$$

where the state variable s_t follows a first order Markov process. The state s_t=1 denotes expansion, while state s_t=2 is recession. The only parameter that changes with the state is the mean of the growth rate. We identify periods of expansion when the mean of output growth is high, and, conversely, periods of recession when the mean is low. We define the transition probabilities as follows:

$$p_{ij} = \Pr\{s_t = i \mid s_{t-1} = j\}.$$

[9] This two-step procedure is implemented because we are trying to capture the behavior of the Fed in periods of output expansion and recession. Estimating a switching regime model and the coefficients of the rules simultaneously delivers states of high inflation and states of low inflation, which is not what we are looking for.

[10] Originally, this model was conceived with autoregressive terms, but this specification seems to be more robust to data revisions. I am thankful to James Hamilton for his comments on this issue.

Therefore,

$$p_{11} = \Pr\{s_t = 1 \mid s_{t-1} = 1\}, \text{ and } \mathrm{p}_{21} = 1 - p_{11}$$
$$p_{22} = \Pr\{s_t = 2 \mid s_{t-1} = 1\}, \text{ and } \mathrm{p}_{12} = 1 - p_{22}.$$

Table 2 presents the estimates. The average growth rate in booms is 4.62 percent, while it is -0.57 percent in recessions, both cases annualized. Booms last longer than recessions. Booms last for an average of 11 quarters (1/(1-p_{11})), while recessions last, on average, roughly four quarters. Also, this estimates suggest that the unconditional probability of being in an expansion is 0.75, while the probability of being in a recession would be 0.25.

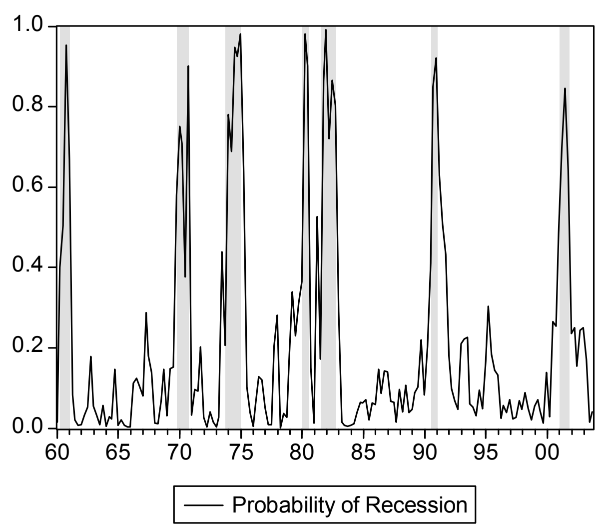
Table 1. Estimates of Switching Regime Model

Variable	Coefficient	Std. Error
$\mu_1=c(s_t=1)$	4.62	0.38
$\mu_2=c(s_t=2)$	-0.57	0.90
p_{11}	0.91	0.03
p_{22}	0.73	0.09
σ	3.35	0.19

Source: Fund staff estimates.

Figure 3 presents the smoothed probabilities of being in an expansion. Reassuringly, and as originally pointed out by Hamilton (1994), periods where the probability is close to one coincide with NBER recession dates. In other cases, the model assigns moderate probabilities of recession.

Figure 3. Probabilities of Being in Recession and NBER Recession Dates



Sources: National Bureau of Economic Research and Fund staff estimates.

In the second stage, the Taylor rule is assumed to be similar to equation (1), but with coefficients changing according to the state of the economy:

$$\begin{aligned} i_t &= \rho(s_t)i_{t-1} + (1-\rho(s_t))(c(s_t) + \gamma_\pi(s_t)\pi_t + \gamma_g(s_t)\Delta y_t) + \varepsilon_t, \\ Var(\varepsilon_t) &= \sigma(s_t)^2 \end{aligned} \tag{2}$$

Hence, the probabilities of being in each state are used to estimate a weighted least squares regression, by minimizing the following loss function:

$$L = \sum_{t=1}^{T} \left\{ \Pr(s_t = 1)\left[i_t - x_t\beta(s_t = 1)\right]^2 + \Pr(s_t = 2)\left[i_t - x_t\beta(s_t = 2)\right]^2 \right\}$$

where $\beta(s_t = i)$ is the vector of parameters (for each state i=1,2) and x_t the vector of explanatory variables (a constant term, inflation, output growth, and the lagged nominal interest rate). As a result, the estimates for the parameters for each state consist in a weighted OLS regression, using the square roots of the probabilities as weights.

An alternative way to derive the estimates for the parameters of the Taylor rule in each state is as follows. The density of the interest rate conditional on the right hand side variables and the state is

$$f(i_t \mid x_t, s_t = j, \beta) = \frac{1}{\sqrt{2\pi}\sigma(s_t = j)} \exp\left\{ -\frac{\left[i_t - x_t\beta(s_t = j)\right]^2}{2\left[\sigma(s_t = j)\right]^2} \right\}.$$

For each observation, the unconditional density of the interest rate (with respect to the state) is a mixture of the conditional densities as follows:

$$f(i_t \mid x_t, \beta) = \sum_{j=1}^{2} \Pr(s_t = j) f(i_t \mid x_t, s_t = j, \beta).$$

By maximizing the log-likelihood of the observed data, $\sum_{t=1}^{T} \log\left[f(i_t \mid x_t, \beta)\right]$, we arrive at the same result: the parameter estimates of the Taylor rule on each state are a weighted OLS regression, using the probabilities of being in each state as a weight.[11]

Table 2 reports the estimates using quarterly annualized rates. The sample period remains 1960 to 2003, using quarterly data. The specification in equation (2), using contemporaneous values for inflation and output is estimated with weighted OLS. The distinction between short-term and long-term response to output and inflation is not so natural as in the case of

[11] See Hamilton (1994, page 696).

fixed coefficients. If we know that recessions tend to be short-lived, it is difficult to interpret the meaning of long-term responses. However, for comparability with previous work, we present both short-term and long term coefficients.[12]

Table 2. Estimates of the Taylor Rule, Switching Regime Model, Using Quarterly Annualized Inflation and Growth Rates

	Short Run Coefficients			**Long Run Coefficients**		
	OLS	Recession	Expansion	OLS	Recession	Expansion
Constant	***-0.34***	-0.22	***-0.31***	-4.41	-2.14	-6.29
	(0.20)	(0.24)	(0.17)	(3.85)	(2.86)	(5.85)
Inflation	**0.14**	**0.10**	**0.17**	**1.77**	**1.00**	**3.45**
	(0.04)	(0.04)	(0.03)	(0.54)	(0.34)	(1.48)
Output	**0.09**	**0.13**	***0.03***	***1.16***	**1.25**	0.71
	(0.02)	(0.03)	(0.02)	(0.59)	(0.61)	(0.58)
Smoothing	**0.92**	**0.90**	**0.95**	**0.92**	**0.90**	**0.95**
	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)	(0.03)
Wald Tests (p-value)		**31.60**	(0.00)		**12.07**	(0.02)

Source: Fund staff estimates.
Notes: Bold means significant at the 5 percent level, bold and italics means significant at the 10 percent level.

Focusing first on the results of the short-run coefficients, three main differences arise: first, the coefficient on the reaction to inflation is almost twice as large as in the case of expansions (0.17) than in recessions (0.10) and, in both cases, the coefficients are significant at the 5 percent level. Second, the coefficient of the reaction of the Taylor rule to output growth is four times as large as in the case of recessions (0.13) than in expansions (0.03). Moreover, in the case of expansions this coefficient is only significant at the 10 percent level. Third, the coefficient on interest rate smoothing is larger in expansions than in recessions, although in both cases they are fairly large (0.95 versus 0.90). Except for the constant term, the OLS coefficients lie in between the two rules. Individually, only the coefficient on output growth is significantly different in the two regimes, but a Wald test suggests that the null hypothesis of all coefficients being equal in the two rules is rejected.

The qualitative interpretation of these results is that the Fed places much more weight on inflation stabilization in expansions, while it shifts its focus to output stabilization in recessions. This shows that the Fed is ready to ease faster in recessions than tighten in booms, because, in recessions, it is precisely when output growth tends to be in negative territory. Finally, interest rate smoothing is higher in expansions that in recessions, as the Fed acts quicker in the latter case.

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[12] That is, the short-term response coefficients are $\tilde{\gamma}_\pi = (1-\rho)\gamma_\pi$ and $\tilde{\gamma}_g = (1-\rho)\gamma_g$, while the long-term responses are given by γ_π and γ_g.

The long-run properties of the two rules are quite different: the coefficient of the reaction of the Taylor rule to inflation is much higher in booms (3.45) rather than recessions (1.00), suggesting that it is in expansion times that the strong anti-inflationary stance of the Federal Reserve is implemented. In recessions, the "Taylor principle" whereby the real interest rate moves more than one-to-one with inflation is not implemented (in fact, the point estimate is 0.9972). The long-run coefficient on output stabilization increases in recessions (it is 0.71 but not significant in expansions, and 1.26 in recessions), again suggesting that when output growth is negative, the Fed eases by a larger amount than when the economy is in expansion.[13] The fact that the rule reacts strongly to (negative) output growth in recessions makes the real interest rate countercyclical.

Table 3 presents the same estimations but using annual growth and inflation rates instead. The main difference with respect to the results of Table 2 is that the coefficients of the reaction of the Taylor rule to output growth are higher, and they are significant at the 10 percent level for the long run coefficient. Also, the Taylor rule, in recessions, does respect the Taylor principle, with a point estimate of 1.14. Finally, the Wald test rejects the null hypothesis of equal coefficients in the two states, both for the short-run and long-run coefficients.

Table 3. Estimates of the Taylor Rule, Switching Regime Model, Using Annual Inflation and Growth Rates

	Short Run Coefficients			**Long Run Coefficients**		
	OLS	Recession	Expansion	OLS	Recession	Expansion
Constant	**-0.66**	**-0.62**	**-0.52**	***-7.91***	-5.98	-9.38
	(0.22)	(0.25)	(0.19)	(4.71)	(3.82)	(6.77)
Inflation	**0.15**	**0.12**	**0.17**	**1.80**	**1.14**	**3.14**
	(0.04)	(0.05)	(0.03)	(0.49)	(0.34)	(1.21)
Output	**0.18**	**0.28**	**0.09**	**2.13**	**2.72**	***1.69***
	(0.03)	(0.05)	(0.03)	(0.91)	(1.08)	(1.00)
Smoothing	**0.92**	**0.90**	**0.94**	**0.92**	**0.90**	**0.94**
	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)	(0.03)
Wald Tests (p-value)		**30.67**	(0.001)		**16.48**	(0.002)

Source: Fund staff estimates.

Notes: Bold means significant at the 5 percent level, bold and italics means significant at the 10 percent level.

[13] We also considered a forward-looking version of the rule, by replacing π_t with $E_t\pi_{t+1}$, and Δy_t with $E_t\Delta y_{t+1}$, where E_t denotes the mathematical expectations operator with information up to time *t*. We estimated such rule with one period ahead expectations of output growth and inflation using weighted two-stage least-squares (TSLS), with the probabilities of expansions and recessions as weights, and four lags of the Federal Funds rate, inflation and output growth as instruments. The qualitative results were similar to the rule that reacts to current values, with the anomaly that the coefficient of the reaction of the Taylor rule to expected output growth turned out to be negative.

IV. Relating the Switching Regime Results to Federal Reserve Chairmen

In this section, we relate the results of the switching regime model to the chairmen that the Federal Reserve has had since 1960, and we try to obtain a pattern between cyclical behavior and Fed chairmanship. In order to fix ideas about the tests we conduct in this section, we start with a simple example. Suppose that we assume that the two-state Taylor rule only reacts to inflation, and we use only a post-83 dummy variable. Then, the model would be:

$$i_t(s_t = 1) = (a(s_t = 1) + d83(s_t = 1))\pi_t$$

$$i_t(s_t = 2) = (a(s_t = 2) + d83(s_t = 2))\pi_t .$$

We run three tests:

(i) All coefficients (including dummies) are jointly equal: $a(s_t = 1) = a(s_t = 2)$ and $d83(s_t = 1) = d83(s_t = 2)$. If we cannot reject this hypothesis, then, the rule followed by the Fed is always the same, regardless of its chairmen and of the state of the economy.

(ii) Only the dummy coefficients are equal: $d83(s_t = 1) = d83(s_t = 2)$, but the level of the coefficients for each state are allowed to change with each chairman. In this case, we assume that the cyclical behavior of the rule is different, but that the shift in the coefficients across states for each chairman is the same.

(iii) If we cannot reject (ii), we fix the dummy coefficient across states, such that $d83(s_t = 1) = d83(s_t = 2) = d83$ and test whether the level is equal $a(s_t = 1) = a(s_t = 2)$. Basically we re-run (i) after imposing the restriction in (ii).

Tables 4 and 5 summarize the results of extending the regressions in the previous sections, using dummy variables for the following periods, when:

- Arthur Burns and William Miller (1970:Q1-1979:Q2) were Fed chairmen,
- The Volcker disinflationary period using non-borrowed reserves targeting took place (1979:Q3-1982:Q4),
- The Fed moved to an interest rate target, with chairmen Volcker and Greenspan (1983:Q1-2003:Q4).

Therefore, we leave the 1960s as the period without dummy variables. In the first row of Table 4, we report the Wald Test (and p-value) of assuming that the coefficients of the two rules in the two regimes (including the set of dummy variables) are the same.[14] We reject the null hypothesis at the 5 percent level, both using quarterly annualized rates and using annual rates for inflation and output growth.

Next, we assume that the dummy effects on each state are the same across chairmen. The Wald test on this restriction is presented in the second row and we find that we cannot reject such restriction. That is, the coefficients of the rule do in fact change across chairmen, but they move by the same magnitude in expansions and in recessions. Next, after imposing that the dummy effects be the same for each period across states, we test whether the levels of the coefficients are jointly different across states in the third row, and we find that we cannot reject such restriction. The next three rows of Table 4 show that the results also hold when only two sets of dummy variables are introduced to control for the Burns-Miller and the Volcker-Greenspan periods.

Table 4: Wald Tests on a Two-State Switching Regime Model with Dummy Variables Related to Fed Chairmen (1960–2003)

Using Dummies for Burns-Miller, Nonborrowed reserves targeting, post-83 periods

Null Hypothesis	Using Quarterly rates		Using Annual Rates	
	Wald Statistic	p-value	Wald Statistic	p-value
All Coefficients are equal	26.42	0.04	32.4	0.009
Dummies for each period across states are equal	16.39	0.17	12.16	0.43
Once dummies for each period across states are held equal, levels of coefficients are equal	9.91	0.04	20.03	0.005

Using Dummies for Burns-Miller, Volcker-Greenspan periods

Null Hypothesis	Using Quarterly rates		Using Annual Rates	
	Wald Statistic	p-value	Wald Statistic	p-value
All Coefficients are equal	30.88	0.002	26.66	0.009
Dummies for each period across states are equal	7.61	0.47	9.84	0.27
Once dummies for each period across states are held	23.46	0.001	16.92	0.002

Source: Fund staff estimates.

Table 5 shows the estimates with dummy variables for the Burns-Miller period and the Volcker-Greenspan period, and after having dropped the coefficients that are not statistically significant.[15] The main differences arise for the 1970s period with respect to the 1960s and the Volcker-Greenspan period. The constant term and the reaction to inflation are fairly

[14] The Wald tests are always performed on the short-run coefficients, since during the Burns-Miller period, a unit root on the interest rate cannot be rejected and hence, the long-term parameters cannot be uncovered.

[15] A Wald test rejects that the four level coefficients (intercept, inflation, output growth and lagged interest rate) are the same across states.

similar across states during the 1960s, and the post-83 period. However, in the 1970s, the short-run reaction to inflation becomes basically zero. The coefficient of the reaction to output is statistically different between recessions and expansions, with no differences between chairmen.

Table 5: Estimates of the Switching Regime Mode with Dummy Variables

	Short Run Coefficients	
	Recession	Expansion
Constant	***-0.45*** (0.25)	**-0.56** (0.16)
Inflation	**0.52** (0.07)	**0.51** (0.05)
Inflation*Burns-Miller	**-0.52** (0.08)	
Output	**0.28** (0.05)	**0.15** (0.03)
Smoothing	**0.61** (0.06)	**0.71** (0.05)
Smoothing*Burns-Miller	**0.35** (0.07)	
Smoothing*Volcker-Greenspan	**0.07** (0.03)	

Source: Fund staff estimates.
Notes: Bold means significant at the 5 percent level, bold and italics means significant at the 10 percent level.

Finally, the degree of interest rate smoothing is lower under recessions than under expansions, and is statistically different in the two states. Compared to the 1960s, both the Volcker-Greenspan and the Burns-Miller periods reflect higher and statistically significant interest rate inertia. The Volcker-Greenspan rule is more stabilizing than in the 1960s because for a given short-run coefficient on inflation, a higher interest rate smoothing value delivers a larger long-run response. On the other hand, the Burns-Miller period delivers coefficients on the reaction of to the lagged interest rate higher than one: as a result it is not possible to derive the short-term responses (which, in any event, are likely to be very close to zero for inflation).

Therefore, the conclusions from this section are: first, the coefficients of the rule shift between expansions and recessions, even when we account for different rules according with Fed chairmen. And second, the Burns-Miller period is characterized by a much smaller reaction to inflation and a larger reaction to lagged interest rates when compared to the 1960s, or after 1983.

V. Implications of a Switching Regime Rule in a Small Scale Macroeconomic Model

So far, this paper has provided evidence that it is possible to characterize the behavior of the Federal Reserve as a two-state Taylor rule, with different coefficients depending on whether the economy is in a boom or in a recession. In what follows, we explore the implications that such rules imply in a small-scale macro model that jointly explains the behavior of output, inflation, and nominal interest rates.

This section presents the simplest version of a New Keynesian model, as in Clarida, Galí, and Gertler (1999), which will be modified to allow for backward looking behavior in both the inflation and output equations, and regime switching in the nominal interest rate rule. In addition to the monetary policy rule, the model has two equations that characterize the dynamics of inflation and output. These equations can be rationalized with a micro founded general equilibrium model, where preferences by households are assumed to have habit formation in consumption, while on the supply side monopolistically competitive firms face nominal rigidities when setting their price, and use backward looking indexation. [16]

In the last decade, a growing part of the macroeconomic literature has emphasized the interaction between nominal rigidities and monetary policy rules, in a variety of contexts.[17] However, most results that come from this class of models have been obtained assuming that information is complete: the central bank observes the value of all variables, shocks, and parameters in the economy and is ready to react optimally to their fluctuations. Similarly, it is common to assume that the monetary policy rule is perfectly observable and credible, and that the coefficients are stable over time.

Hence, it is not surprising that, parallel to the development of the "New Keynesian" literature, many papers have emphasized the important implications of departing from the assumption that information is complete at all levels. One branch of the literature assumes that the private sector does not have perfect knowledge or observability about the monetary policy rule. This assumption is used to model lack of credibility of the central bank's policy: Erceg and Levin (2003) and Schorfheide (2003) look at the effects of a change in the monetary authority's inflation target that agents learn over time. Rabanal (2002) studies the properties of an economy where agents learn the monetary policy rule using discounted least squares. Misperceptions about the policy rule might imply additional volatility and persistence in output and inflation.

The idea that we capture in the next subsections is that while long-term expectations are anchored by the historical behavior of the central bank, when a given shock causes a

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[16] In order to save space, the equations show variables as linear approximations to their steady state values. Microfounded versions of the New Keynesian model can be found in Woodford (2003).

[17] See the extensive survey in Clarida, Galí, and Gertler (1999), and the book by Woodford (2003).

recession to the economy, the central bank switches to “recession mode” to stimulate the economy. The information is perfect, in the sense that all agents know that the Fed has switched to recession mode, which becomes public knowledge. We will not be dealing with credibility issues as they do not seem to be relevant to the case of the United States. Nonetheless, we would completely agree that these issues are of central importance for countries with central banks that do not have a reputation of being hawkish on inflation in the long run.

A. The Model

The inflation equation is the so called New Phillips Curve, or also known as the AS curve:

$$\pi_t = \gamma_b \pi_{t-1} + (1-\gamma_b) E_t \pi_{t+1} + \lambda y_t + u_t, \tag{2}$$

where π_t is the inflation rate, y_t is the output gap, E_t denotes the expectations operator using information up to time *t*, and u_t is a cost push shock. The parameter γ_b is related to the amount of price setters that follow a backward looking rule when setting prices. This equation can be derived as a first order approximation to the optimal price chosen by a firm that keeps its price fixed at random time intervals, as in Calvo (1983), and with backward looking indexation.

The second equation reflects the dynamics of the output gap:

$$(1+b) y_t = b y_{t-1} + E_t y_{t+1} - (1-b)(i_t - E_t \pi_{t+1}) + g_t, \tag{3}$$

where i_t is the nominal interest rate and g_t is a demand shock. *b* denotes degree of habit formation in consumption, and also relates output to the real interest rate.[18] This equation is derived as a linear approximation to a consumption Euler equation. The demand shock reflects components of GDP that do not react to the real interest rate, such as government expenditures.

To see the importance of the monetary policy rule in the model, let’s assume that the model is entire forward looking (that, is, that γ_b and *b* are set to zero) and that all shocks are set to zero. Then, the dynamics of output and inflation become:

$$\pi_t = \lambda \sum_{i=0}^{\infty} E_t y_{t+i}$$

$$y_t = \sum_{i=0}^{\infty} E_t (i_{t+i} - E_t \pi_{t+i+1}).$$

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[18] In order to preserve balanced growth, preferences are logarithmic in the quasi-difference of consumption. That is, the utility function reads $u(c_t, c_{t-1}) = log(c_t - bc_{t-1})$.

Clearly, not only does the current value of the nominal interest rate matter, but also the way the policy rule is perceived by the private sector. The way the private sector perceives the policy rule affects its expectations, which feed back into the current values of the two endogenous variables. Hence, it is important for the private sector to understand which part of the value of i_t belongs to *systematic* responses of the central bank to output and inflation fluctuations, and which part belongs to unexpected monetary policy shocks, when forming expectations about the future path of monetary policy. Obviously, the higher is the coefficient of the reaction of output to the real rate of interest, the more important the expectations channel will be.

The calibration that we use to conduct simulations in this section is as follows: we use a coefficient of $\gamma_b = 0.5$, consistent with evidence that suggest that inflation dynamics in the U.S. equally weights forward and backward looking behavior (Fuhrer and Moore, 1995). The range of estimates for λ in the literature is wide, so we choose a somewhat intermediate value of 0.2, suggested by Rotemberg and Woodford (1997). We use a value for the habit formation parameter of b=0.5, consistent with the estimates of Galí and Rabanal (2004).

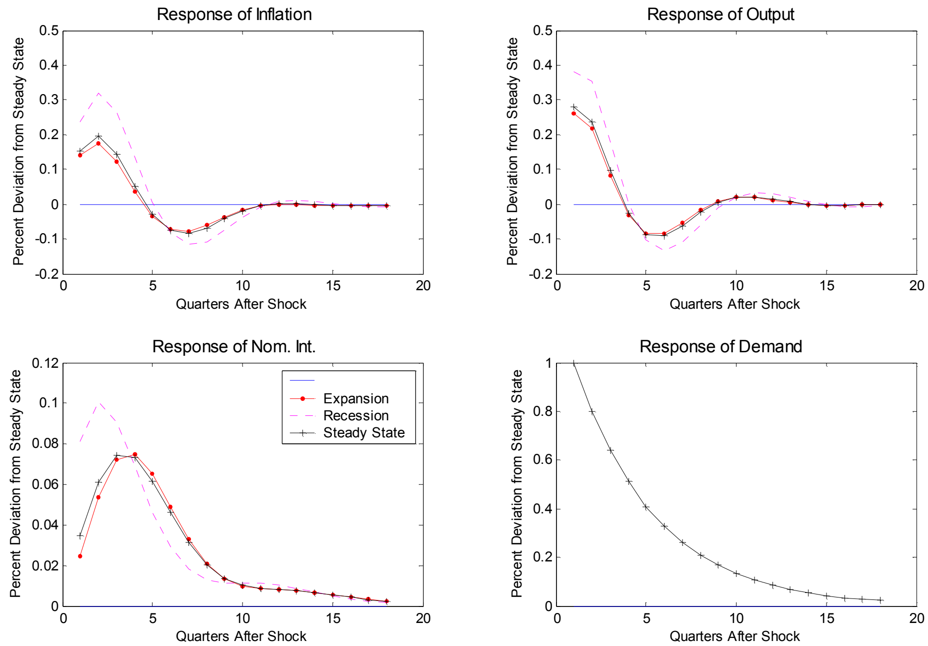
We assume that the Federal Reserve follows a Taylor-type rule like the one that we modeled and estimated in section IV. We take the coefficients from Table 3, rounding them but always staying in the 95 percent confidence interval. In recession, the coefficients are $\rho = 0.9, \gamma_\pi = 1, \gamma_y = 1.5$; in expansion $\rho = 0.95, \gamma_\pi = 3.5, \gamma_y = 0$; and in steady state we use $\rho = 0.9375, \gamma_\pi = 2.5, \gamma_y = 0.6$. The latter comes from the fact that, according to Hamilton's switching regime model estimates, the economy is three-fourths of the time in expansion, and one-fourth in recession.

B. Impulse Responses

This subsection presents impulse responses to cost push and demand shocks under the two type of rules that were estimated in section IV, that we label "recession" and "expansion" rules, assuming that the Fed does not switch rules. In both cases, the autoregressive coefficient of the shocks is set to 0.8. We also present the behavior under a "steady-state" rule, which would be the one that agents expect to hold in the long run.

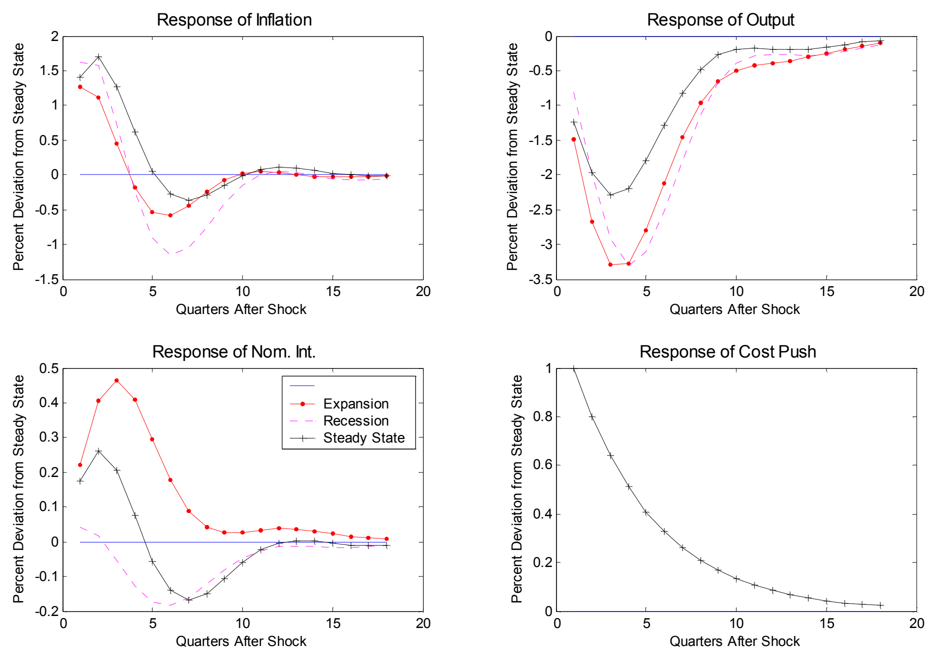
Figure 4 shows the impulse response to a demand shock. The "recession" rule induces more volatility in the system. By not reacting enough to inflation fluctuations, the central bank ends up creating more volatility in output and inflation, which is translated into higher volatility of the nominal interest rate. Not surprisingly, the dynamics under the "steady state" rule are closer to the "expansion" rule, because the former also includes a substantial amount of "inflation targeting."

Figure 4. Impulse Response to a Demand Shock



Source: Fund staff simulations.

Figure 5. Impulse Response to a Cost-Push Shock



Source: Fund staff simulations.

In the impulse response to a cost-push shock (Figure 5), output volatility is quite similar under the two rules, but inflation becomes more volatile under the "recession" rule. Moreover, since the recession rule targets output growth when it is below potential, it is able to reduce the initial jump of output. However, the maximum loss is quantitatively similar to the "expansion" case, only to be delayed by one quarter. Interestingly, the steady state rule does not generate output and inflation dynamics that lie between the two extreme cases, even though the interest rate does so. With the steady state rule, inflation is more volatile and output is much less volatile than in the other two cases, showing the stabilization properties of a rule that implies strong inflation targeting with some scope for output stabilization.

Figures 4 and 5, while being very illustrative on the properties of each policy rule, have some limitations. The main one is that, under all cases considered, it does not matter if the shock generates a boom or a recession, because the response in all cases is symmetric. That is, a negative demand shock or cost push shock would generate the same outcome but with a reversed sign. In Figures 6 and 7, we display the case when the central bank conducts policy in an asymmetric way. In order to focus on the relevant cases, we generate the shocks that cause a drop in output (i.e., a negative demand shock and a positive cost-push shock). An important feature of these impulse-responses is that agent's expectations include going back to an "average" or steady state rule in the long run. If the Fed abandons its anti-inflationary stance in the short run, it does not mean, if it has credibility, that it will abandon it in the future.[19]

Figure 6 displays the effects of a negative demand shock, and the reaction of the Fed under the "state dependent" rule. We also have plotted, for comparison purposes, the "steady state" or long-run rule, which simply behaves as the mirror of the one in Figure 4. The main conclusion from this figure could somehow be anticipated from previous results: since the "recession" rule creates more volatility, the state-dependent rule under recession also creates more volatility in inflation and output. Both output and inflation fall for one additional period after the negative shock hits the economy. The recovery, however, takes the same time, about four periods, and the rebound is larger under the state-dependent rule than otherwise.

The dynamics of the state-dependent rule become more interesting when a positive cost-push shock hits the economy, displayed in Figure 7: interest rates increase on impact (because of the initial focus on inflation) but decrease afterwards (because of the focus on output growth). As a result, output seems to recover faster from the shock, but eventually inflation picks up, the central bank tightens again, and output ends up displaying an oscillatory behavior.

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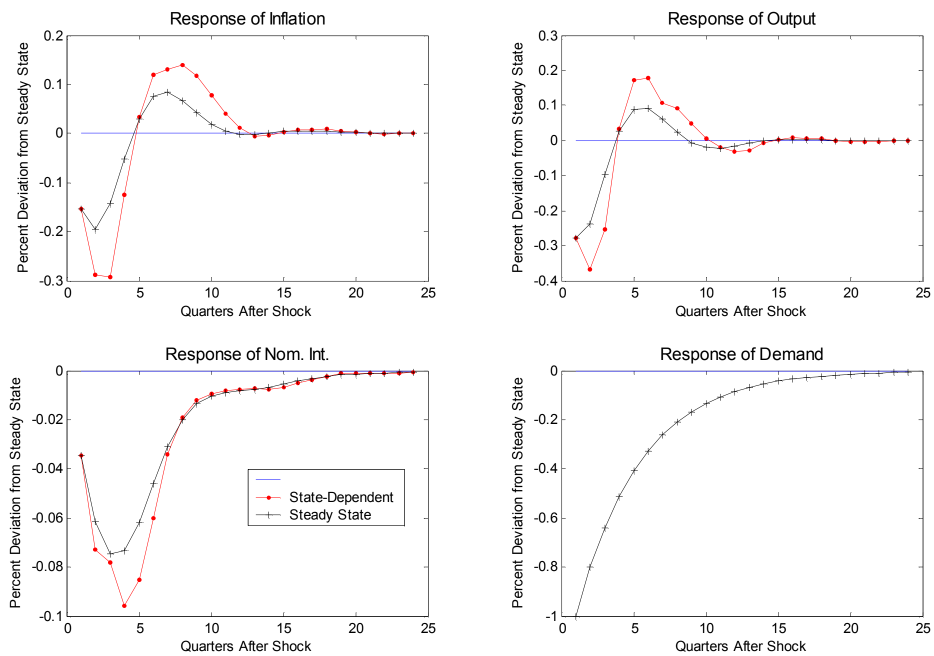
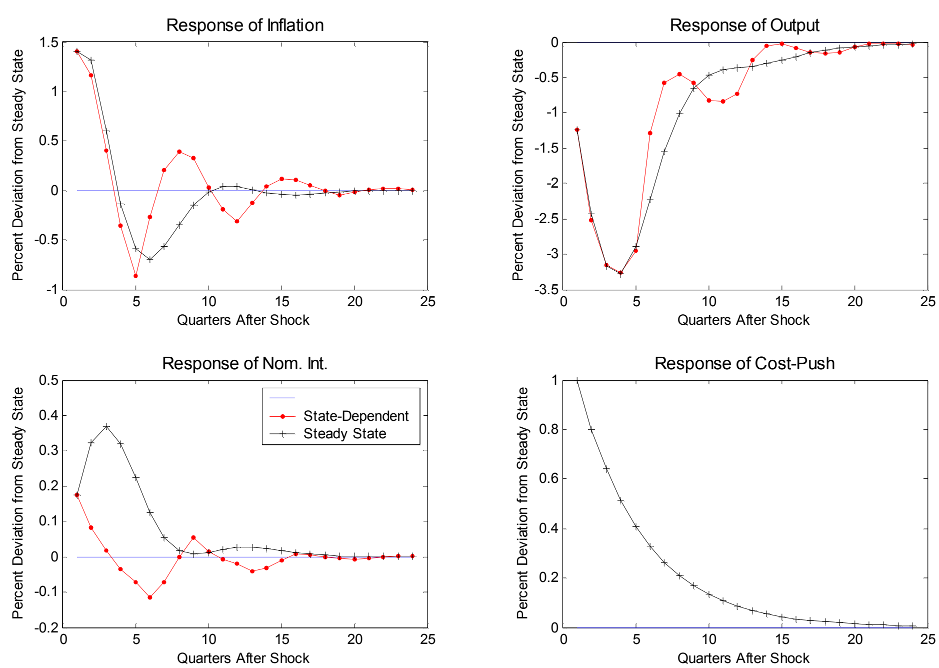
[19] Obviously, this would be an extremely interesting area of research, but outside the scope of this paper.

Figure 6. Impulse Response to a Demand Shock with a State-Dependent Rule



Source: Fund staff simulations.

Figure 7: Impulse Response to a Cost-Push Shock with a State-Dependent Rule



Source: Fund staff simulations.

C. Second Moments

This subsection complements the impulse-response analysis, by conducting a simulation to examine how much volatility (or stabilization) each rule provides, conditional on each shock. In every case, we run 1000 simulations of length 180 each (corresponding to 45 years). The results are displayed in Table 6.

Table 6. Volatility of Inflation, Output and Interest Rates
(depending on each rule)

	Cost Push Shock				Demand Shock			
	Rec.	Exp.	Steady State	State Dependent	Rec.	Exp.	Steady State	State Dependent
Inflation	3.10	1.99	2.32	3.14	0.53	0.29	0.32	0.45
Output	6.43	6.58	6.47	6.15	0.59	0.38	0.41	0.50
Int. Rates	0.35	0.82	0.65	0.18	0.18	0.15	0.15	0.16

Source: Fund Staff simulations.

With cost-push shocks present, the expansion rule does a better job in stabilizing inflation, which is not surprising since it is an inflation targeting rule, but the recession rule stabilizes the volatility of output better. The steady state rule delivers a somewhat intermediate result. Interestingly, the state-dependent rule does not deliver an intermediate result: inflation volatility is the highest (although only marginally larger than the recession rule) but output volatility is the lowest. This result is of relevance because it will be up to the central bank (or society as a whole) to decide if it is worthwhile to accept higher inflation volatility in order to induce lower output volatility at the times of recession, or not. Also, the state-dependent rule also delivers the least volatility of the nominal interest rate under cost-push shocks, which suggest that policy announcements and the management of expectations have as much powerful impact as adjusting the value of the policy interest rate.

On the other hand, under demand shocks, the ranking of rules is clearer. The strict inflation targeting “expansion” rule is the one that delivers the smallest variability in all variables. The steady state rule does a good job, while the switching rule and the recession rule perform, in this order, much worse. This result is not surprising given that, in this class of models, the optimal rule under demand shock can indeed stabilize both inflation and output perfectly, and the trade-off between inflation and output comes from cost-push shocks.[20]

[20] See Clarida, Galí, and Gertler (1999).

To conclude this section, we would like to mention that we repeated the previous exercises assuming a purely forward looking model ($b = 0$, $\gamma_b = 0$), with only habit formation but pure forward looking inflation, ($b = 0.5$, $\gamma_b = 0$) and with only backward looking behavior in the inflation equation ($b = 0.$, $\gamma_b = 0.5$), finding very similar results from a qualitative point of view.

VI. CONCLUDING REMARKS

Much debate has been devoted recently to the suitability of the Taylor rule in characterizing the behavior of the Federal Reserve, especially in abnormal times. This paper has presented evidence that the coefficients of the Taylor rule do, indeed, change both with time and with economic conditions. In particular, during expansions the Fed operates as a strong inflation targeter with a high degree of policy inertia, while during recessions it targets output growth and moves faster. We have related the switching regime model with recent monetary policy history. We found that during the Burns-Miller period, the degree of response of the nominal interest rate to inflation was very low, and the degree of interest rate inertia was much higher than with respect to the 1960s or the post-1983 period.

The second part of the paper presented some simulation results, which, in the context of the model, point at strict inflation targeting as the best policy rule. When the economy is experiencing a recessionary supply shock, however, it might be worthwhile adopting a switching regime rule, as it is the option that minimizes the variability of output in periods of recession; an outcome that the central bank might want to consider, even at the cost of higher inflation variability.

Introducing nonlinear elements into the model seems to be worth pursuing in future research. We have assessed the behavior of nonlinear rules in the context of linear models. It is well known that models of optimal monetary policy with quadratic loss functions and linear constraints deliver linear rules as optimal, even under uncertainty. It would be worthwhile exploring the optimality of switching regime rules when either the loss function is not quadratic or when the constraints are nonlinear. Dolado, María-Dolores, and Ruge-Murcia (2003) and Dolado, María-Dolores, and Naveira (2004) have studied optimal nonlinear Taylor rules under asymmetric preferences or nonlinear Phillips curves. The literature on consumption and precautionary savings (Deaton, 1992), suggests a role for nonlinear Euler equations in output.

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